

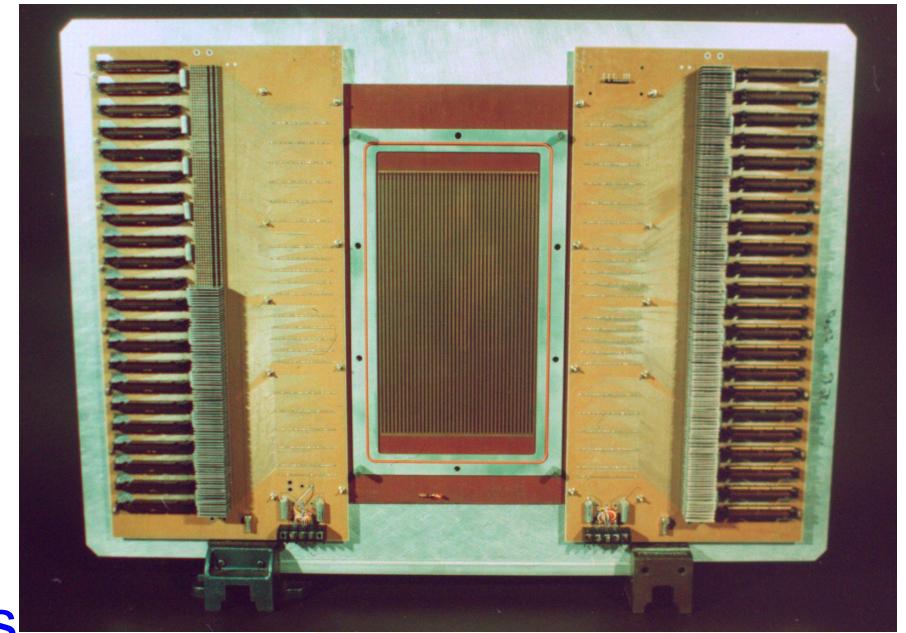


Micropattern Gas Detectors

V. Polychronakos

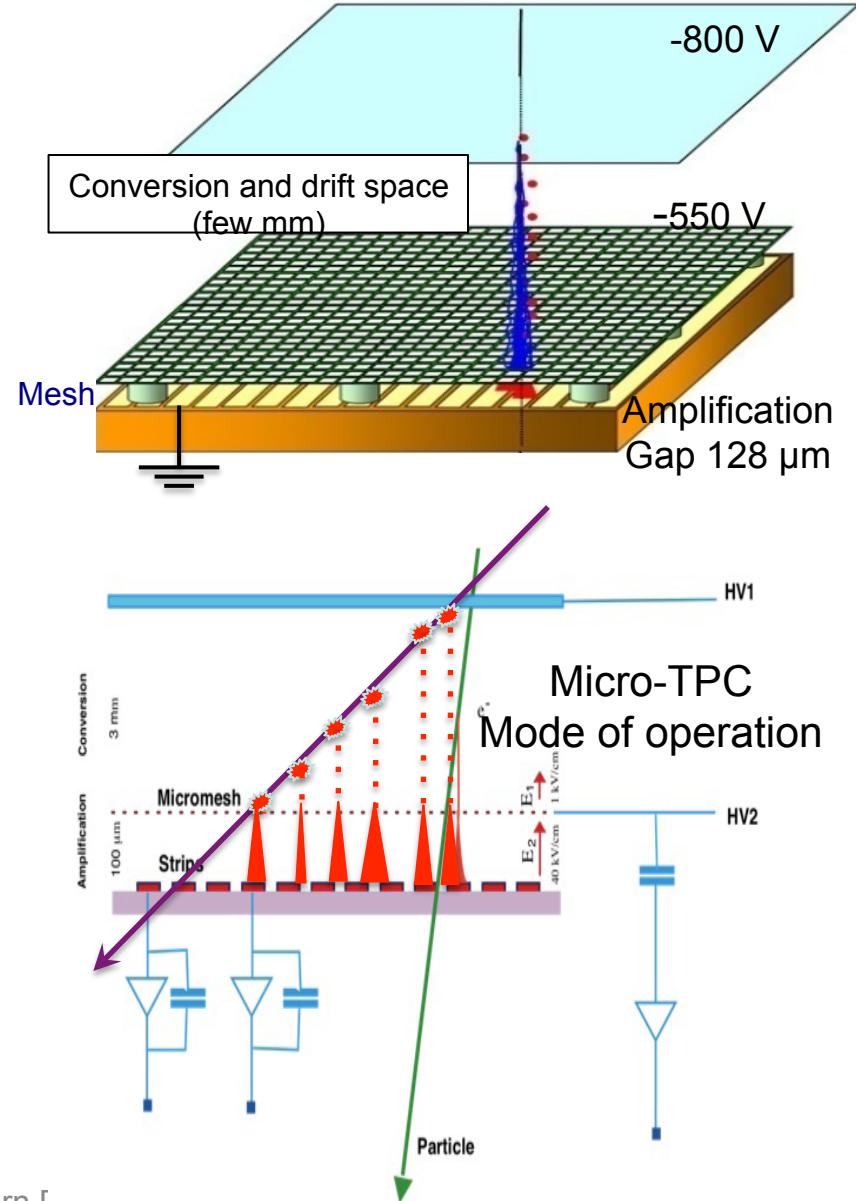
Micromegas R&D, Some Background

- Mid-80s “Pad” Detectors (E814)
 - ◆ $1 \times 2 \text{ mm}^2$ pads, resistive readout
 - ◆ 1016 channels, discreet preamps, shapers and digitizers in Fastbus crates!
 - ◆ Heavy multi-coax cables carrying analog preamp signals
- Mid-90s Cathode Strip Chambers
 - ◆ For GEM at the SSC later used in ATLAS and CMS
- Micropattern Detectors the natural next step
- Parallel R&D on Electronics and always in collaboration with Instrumentation Division



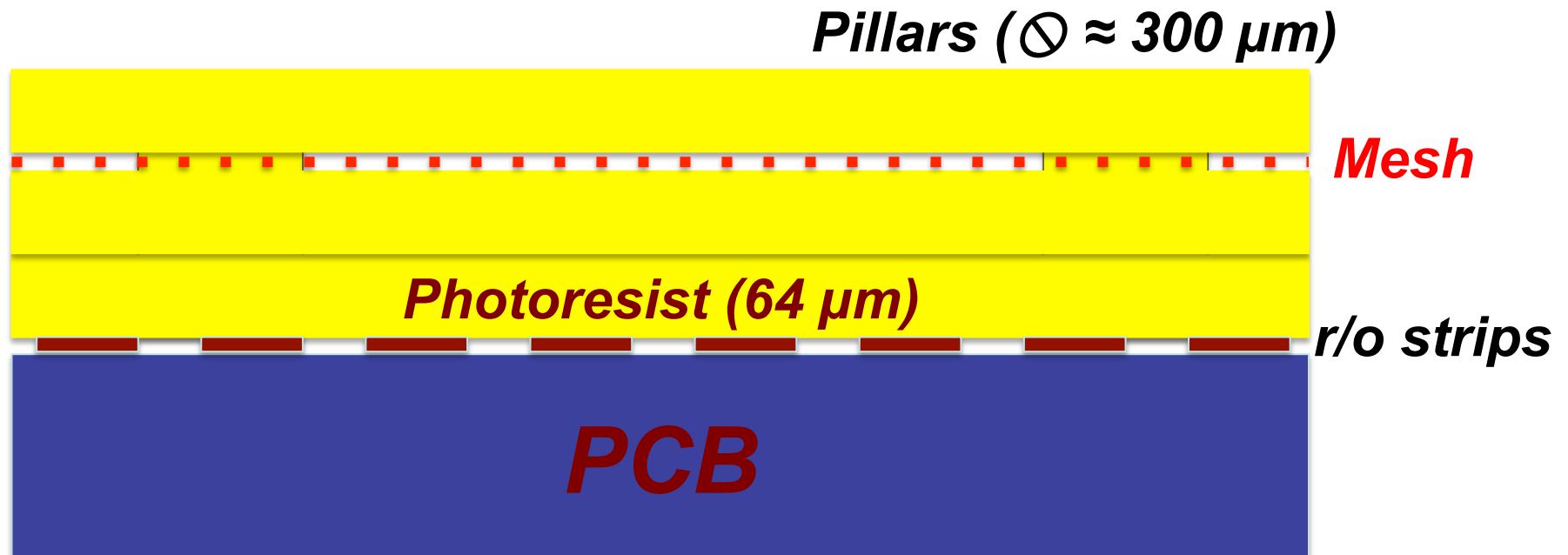
Micromegas operating principle and Key Features

- Micromegas (I. Giomataris et al., NIM A 376 (1996) 29) are parallel-plate chambers where the amplification takes place in a thin gap, separated from the conversion region by a fine metallic mesh
- The thin amplification gap (short drift times and fast absorption of the positive ions) makes it particularly suited for high-rate applications
- High electrical field (40–50 kV); typically a factor 70–100 is required to make the mesh fully transparent for electrons
- Small charge footprint ($\sim 300 \mu\text{m}$)
 - Excellent spatial and double track resolution
 - Operation in “micro-TPC mode for measuring steeply inclined tracks



The bulk-micromegas* technique

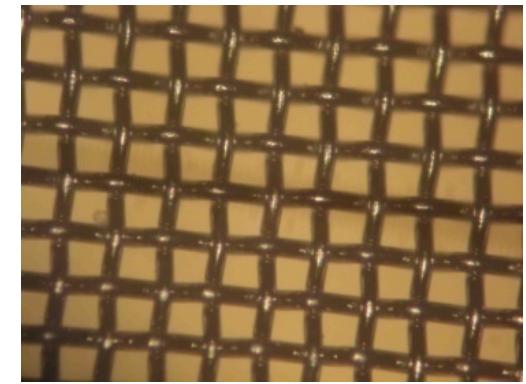
*The bulk-micromegas technique, developed at CERN,
opens the door to industrial fabrication*



**) I. Giomataris et al., NIM A 560 (2006) 405
Rui de Oliveira (CERN PC Lab)*

Bulk-micromegas structure

Pillars (here: distance = 2.5 mm)

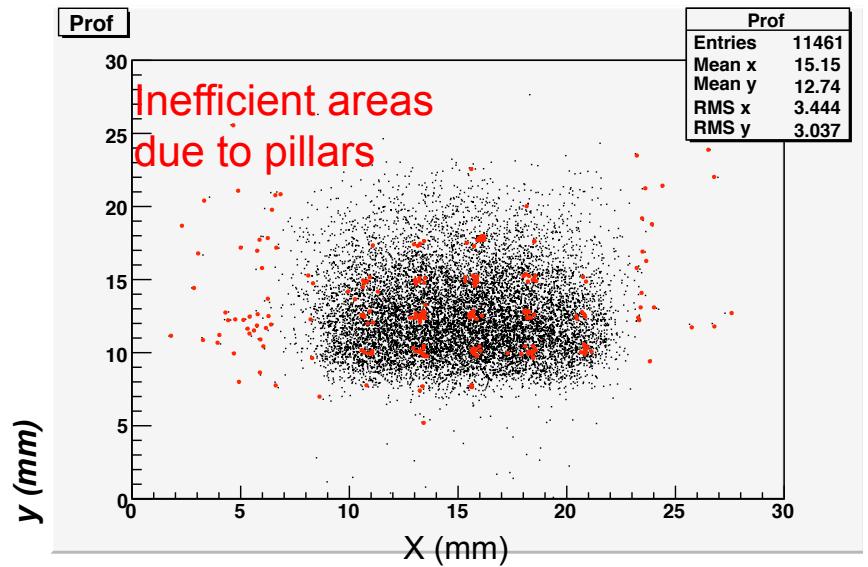
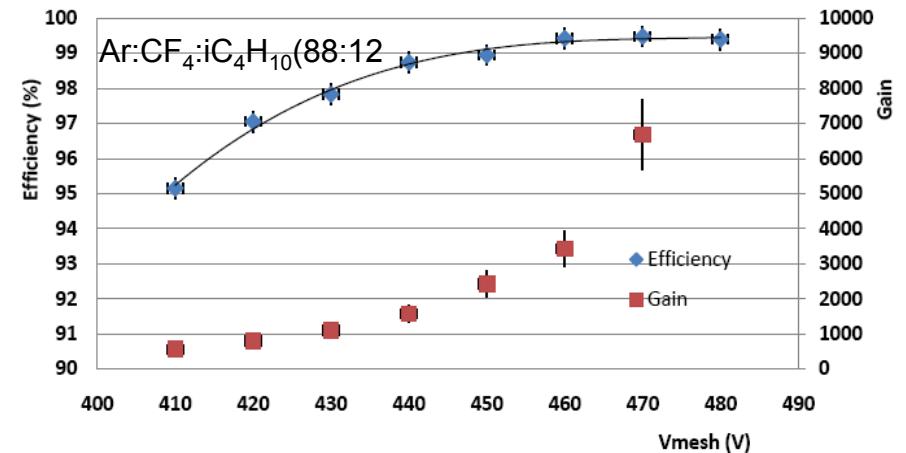
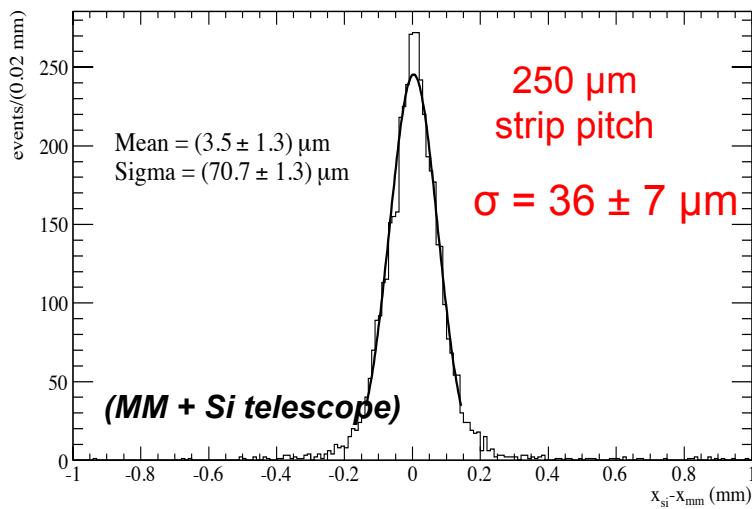


Standard configuration

- Pillars every 2.5 – 10 mm
- Pillar diameter \approx 300 μm
- Dead area \approx 1–2%
- Amplification gap 128 μm
- Mesh: 350 wires/inch
- Wire diameter 20 μm

Status ca 2008: Demonstrated performance

- Standard micromegas (P1)
- Safe operating point with efficiency $\geq 99\%$
- Gas gain: $3-5 \times 10^3$
- Very good spatial resolution



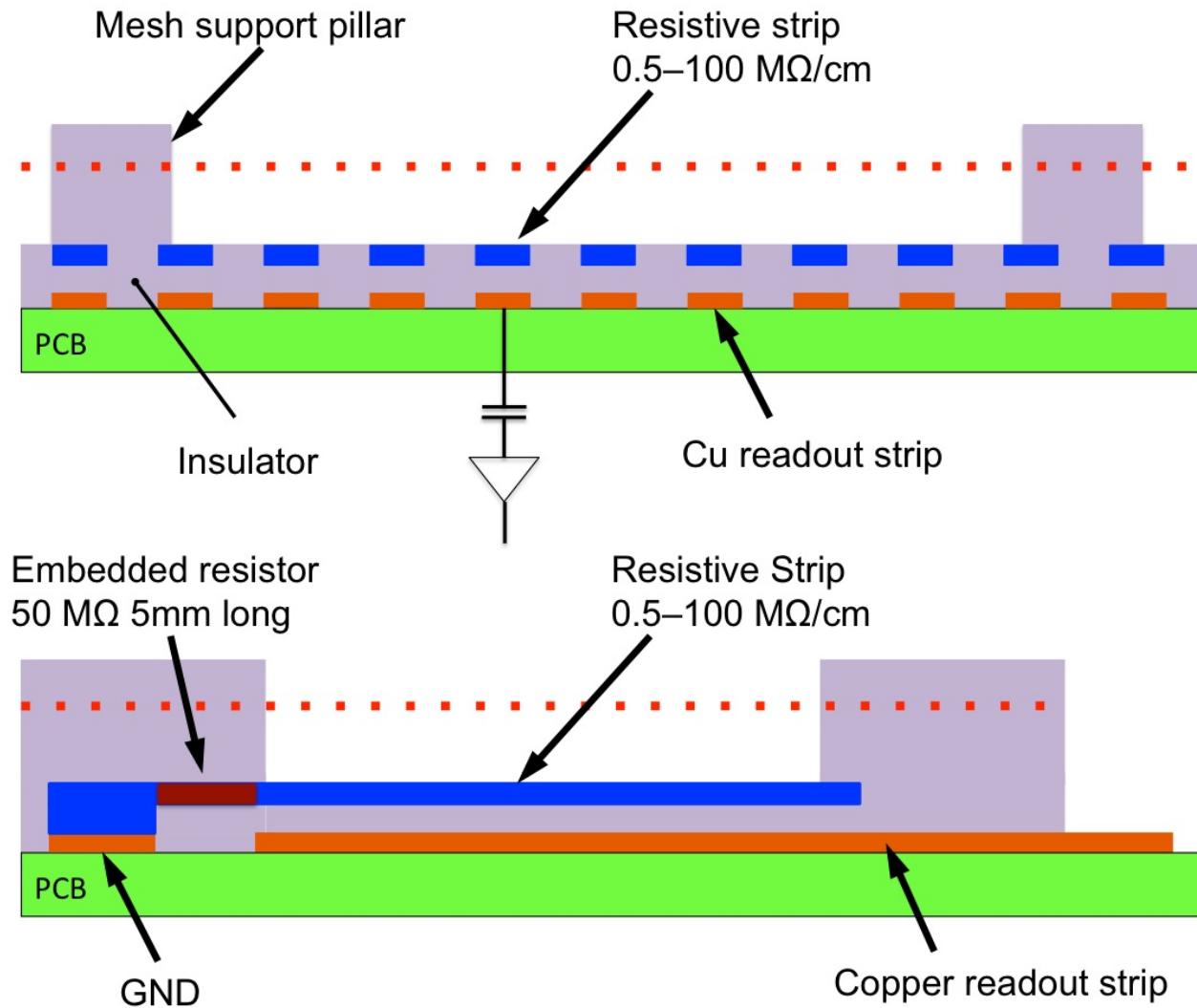
Established technology – Used in COMPASS, T2K (72 Detectors 35x36 cm²)
But prone to discharges (sparks) make it impossible to operate in a Hadronic environment

2010: Making MMs spark resistant

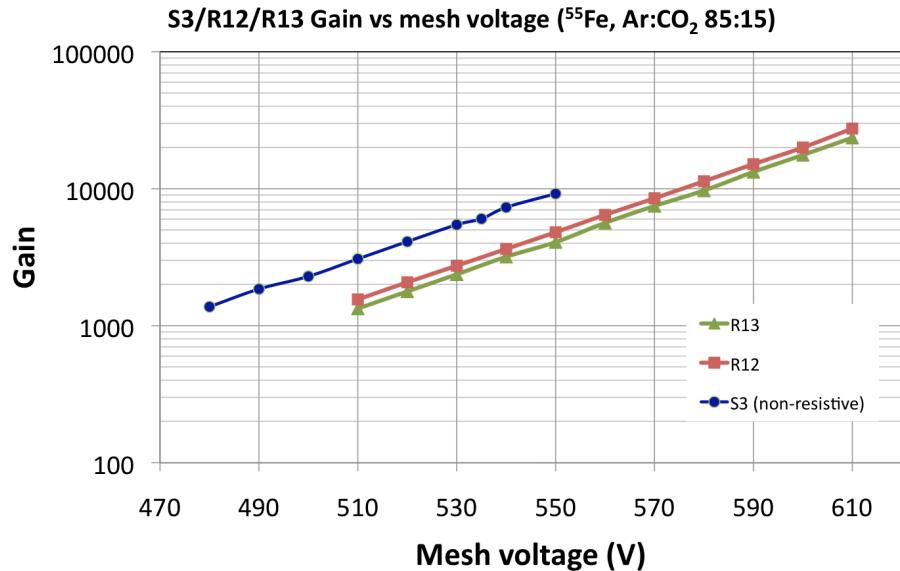
CERN (De Oliveira, Wotschack)
BNL (V.P., Cherniatine)
NTUA, Athens, Alexopoulos

- Tested several protection/suppression schemes
 - A large variety of resistive coatings of anode
 - Double/triple amplification stages to disperse charge, as used in GEMs (MM+MM, GEM+MM)
- Settled on a protection scheme with resistive strips
- Involvement of U.S. Industry to fabricate large area detectors (Triangle Labs, NV, fabricated small detector with help from BNL PC Lab techs)

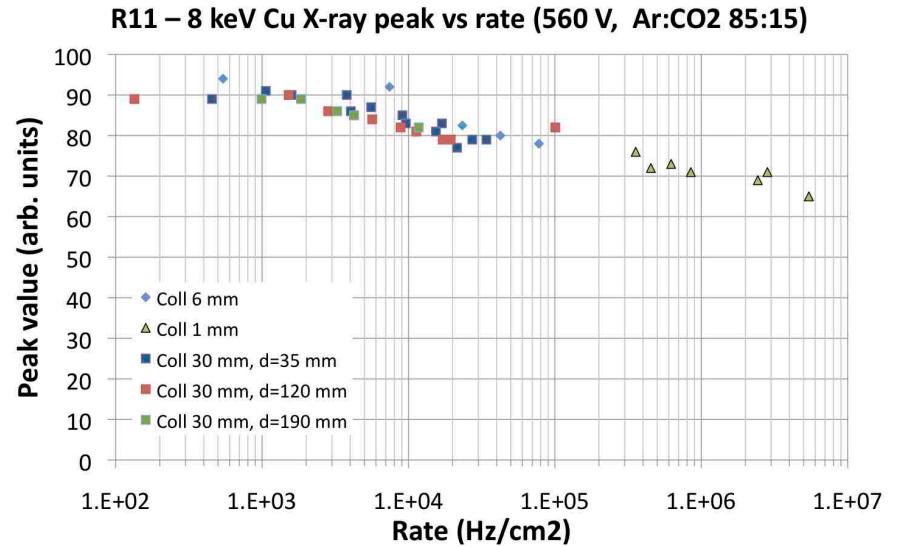
The resistive-strip protection concept



Some Results of the Resistive Detectors



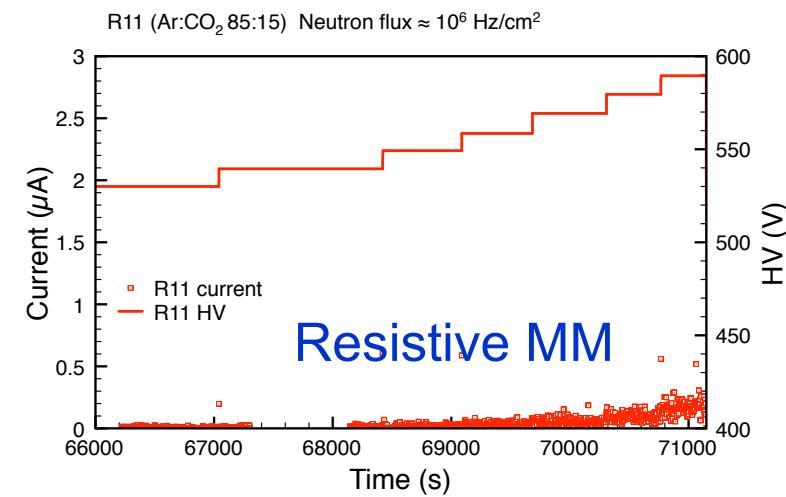
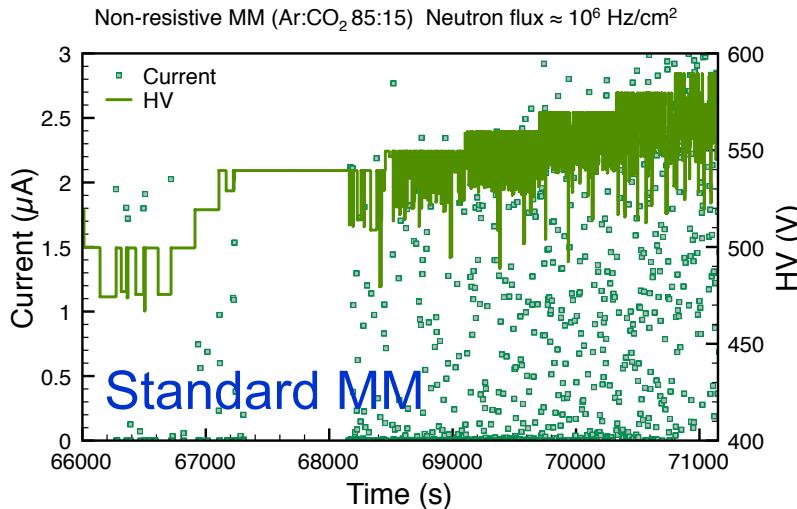
Gas gain as a function of HV for a “standard” detector (blue) and two resistive ones



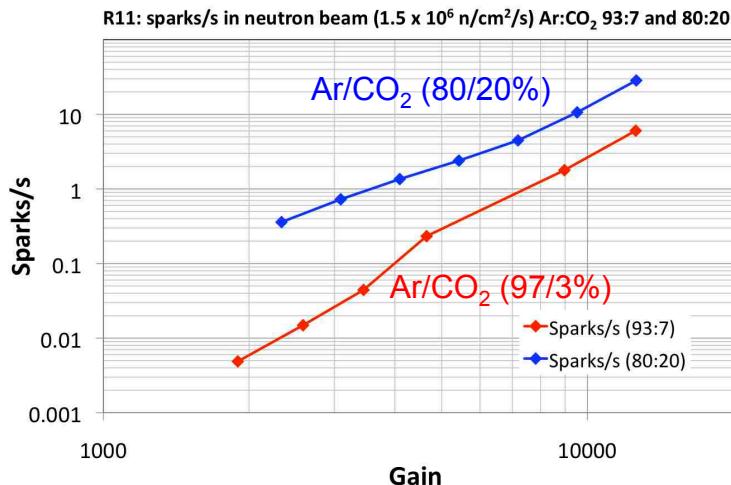
Gain vs rate in an intense X-ray beam

- ❑ Detectors extensively tested with sources, x-rays, particle beams, neutrons
- ❑ Well behave under rate conditions higher than even future LHC conditions
- ❑ In tests with X-rays, MHz/cm² rates measured with modest gain reduction

Performance in neutron beam



HV break-down and currents of several μA



Spark rate in a 10x10 cm² Detector
Neutron rate $\sim 10^6$ n/cm²

October 3, 2012

No HV drops, low currents gas gains of 2×10^4

R11: Interaction & spark rate/neutron (Ar:CO₂ 93:7 and 80:20)

Rate

Gain

Interactions/n (93:7)

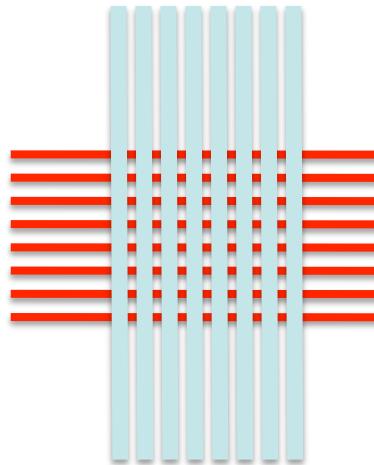
Interactions/n (80:20)

sparks/n (93:7)

sparks/n (80:20)

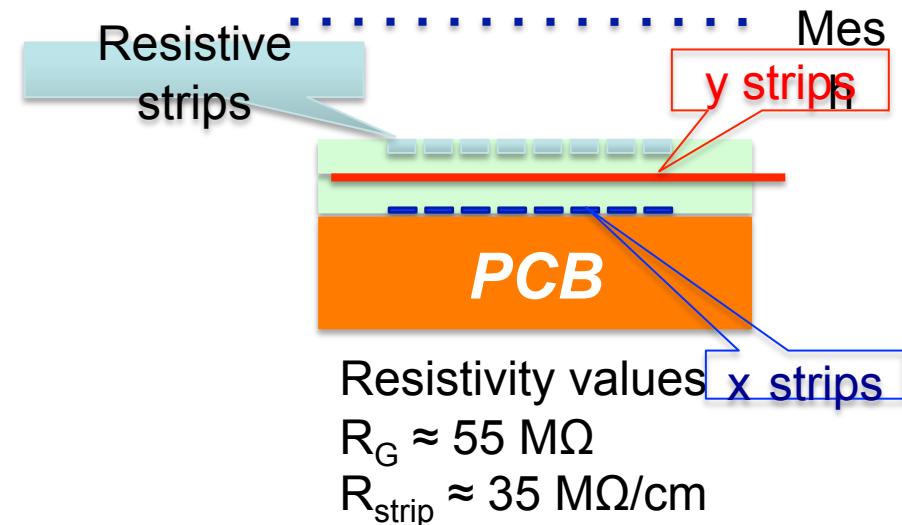
Neutron detection efficiency (top set) and
spark rate for two CO₂ concentrations
Micropattern Detector R&D

Further Developments - 2D readout

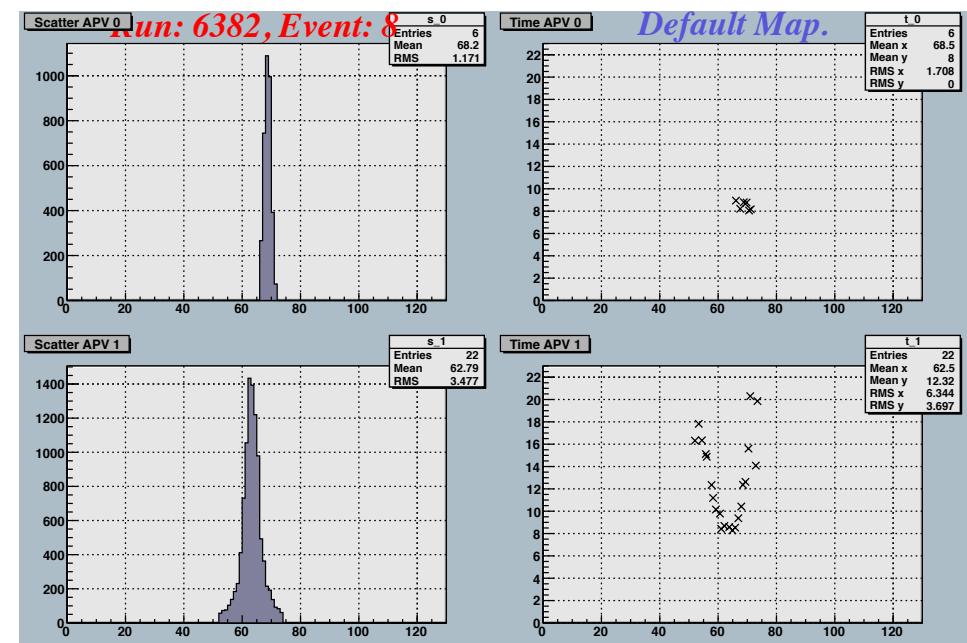


x strips: 250/150 μm
r/o and resistive strips

y: 250/80
 μm
only r/o
strips



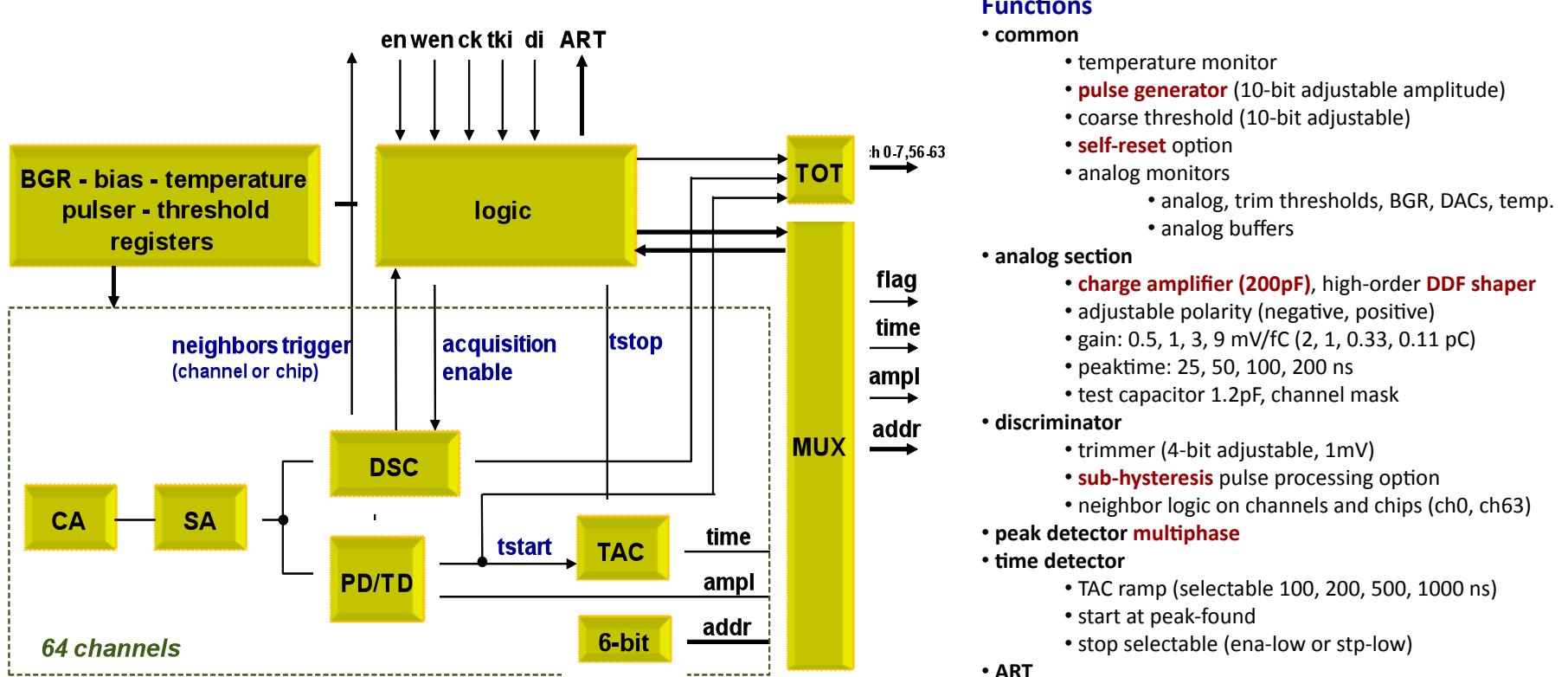
Two coordinates in same gas gap
Amplitude (left plots) and time (right)
for the readout strips parallel to the
resistive (top) and orthogonal to the
resistive strips
Notice spread of charge across strips in
the orthogonal coordinate



Development of a Custom Front End IC

- The small (~300 μm) charge footprint of mMegas detectors results in excellent spatial and double track resolution, but also in a large number of channels
- Important to develop a front end IC along with the detector
- Versatile design appropriate for a variety of detectors
 - ◆ Micromegas, GEM, MWPC, TGC, even silicon
 - ◆ Selectable polarity, peaking time, dynamic range
 - ◆ Built on a concept developed at BNL Instrument. Div. (G. de Geronimo)
 - Peak detection and time stamp
 - ◆ Built-in digitizers
 - ◆ Trigger Primitives in real time
 - ◆ Data driven, sparse readout
 - ◆ Smart token readout makes it pretty much a DAQ on a chip
 - ◆ Minimal external circuitry required

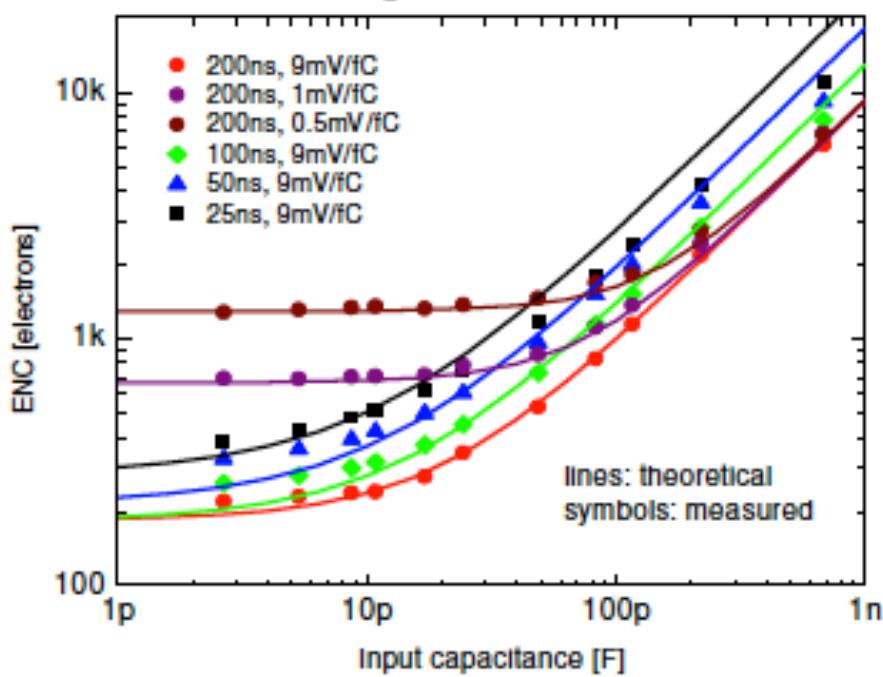
Operation and functions – First Version, No Digitizers



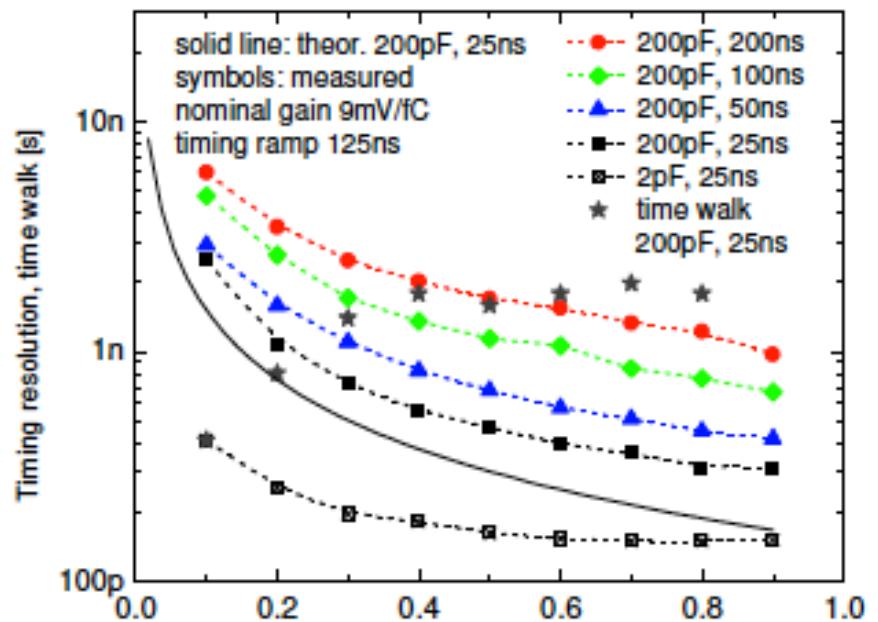
Modes of operation

- **acquisition**: events are detected and processed (amplitude and timing)
 - charge amplification, discrimination, **peak- and time-detection**
 - address in real time (**ART**) of the first event
 - direct timing (**ToT** or **TtP**) per channel for channels 0-7 and 56-63
- **readout**: sparse mode with **smart token** passing (amplitude, timing, addr.)
- **configuration**: access to global and channel registers

Some early test results of the first version of the IC



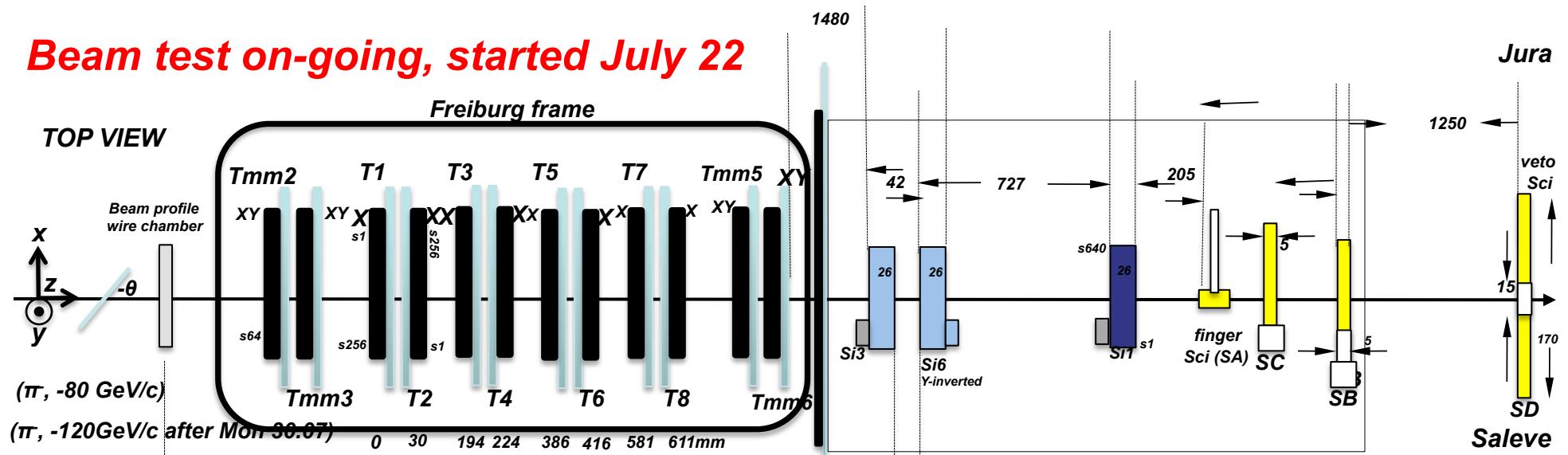
Measured and calculated RMS noise for various Gains and Integration times



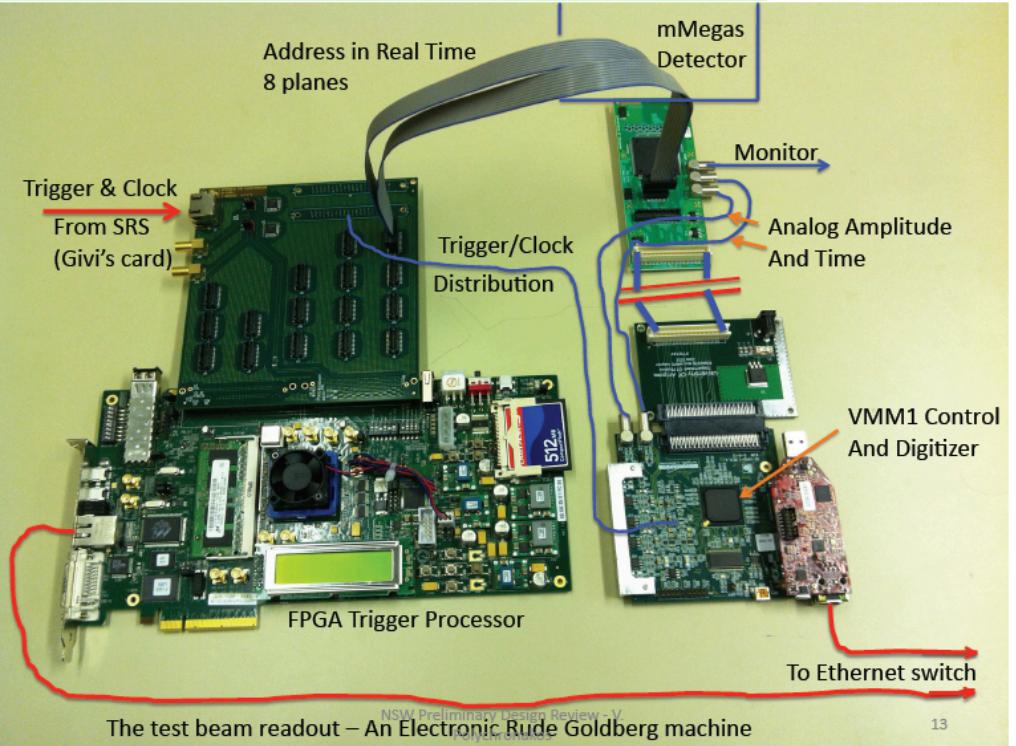
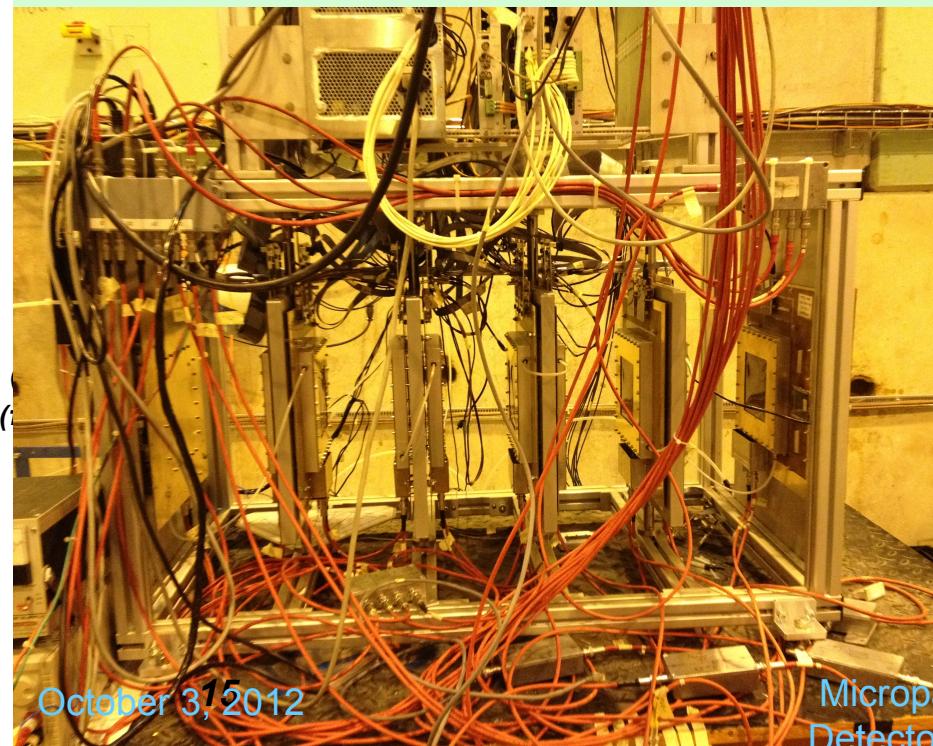
Time resolution and Time Walk as a function of Amplitude

TEST BEAM SETUP Jul-Aug2012 (27.07.2012-10.08.2012)

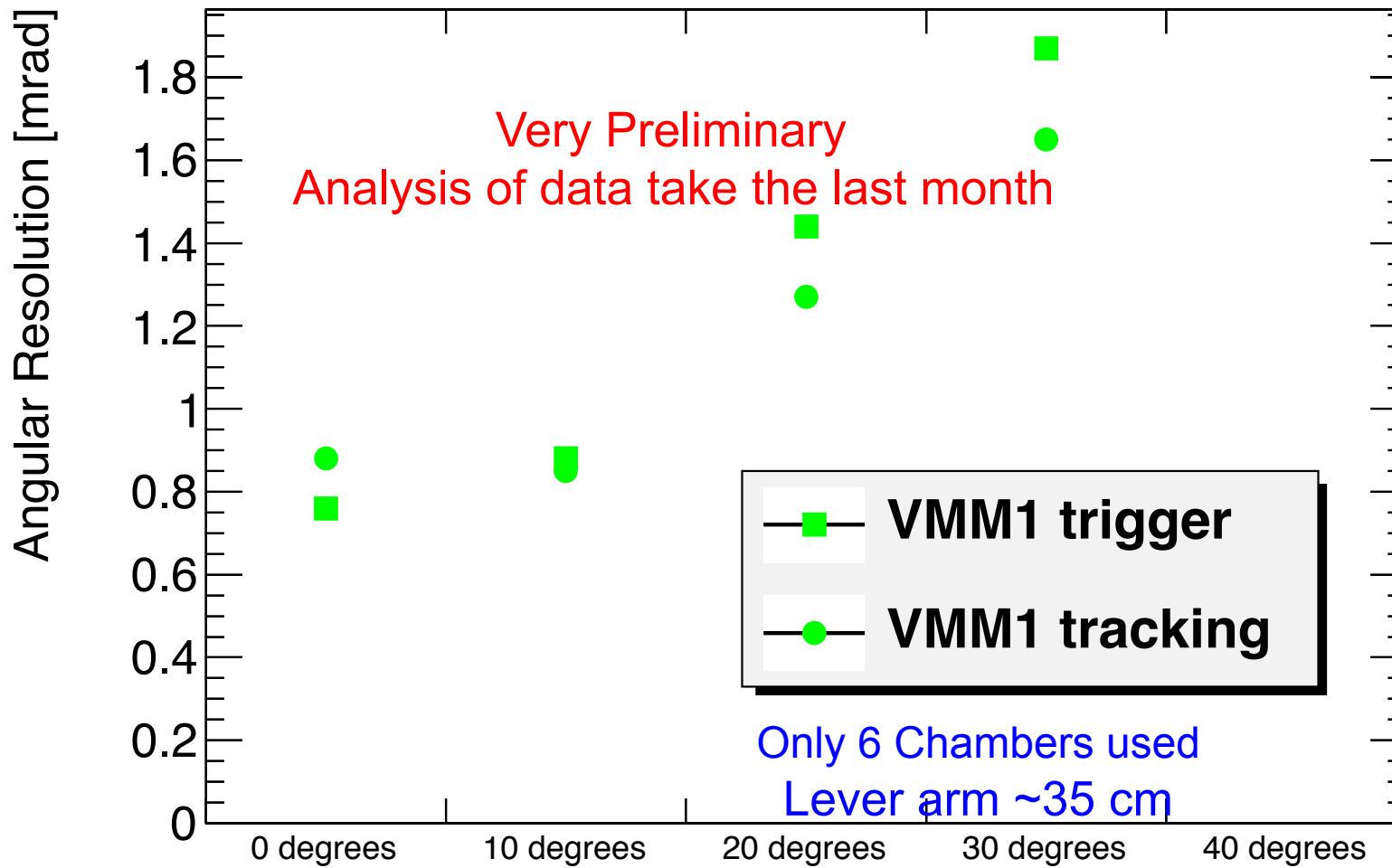
Beam test on-going, started July 22



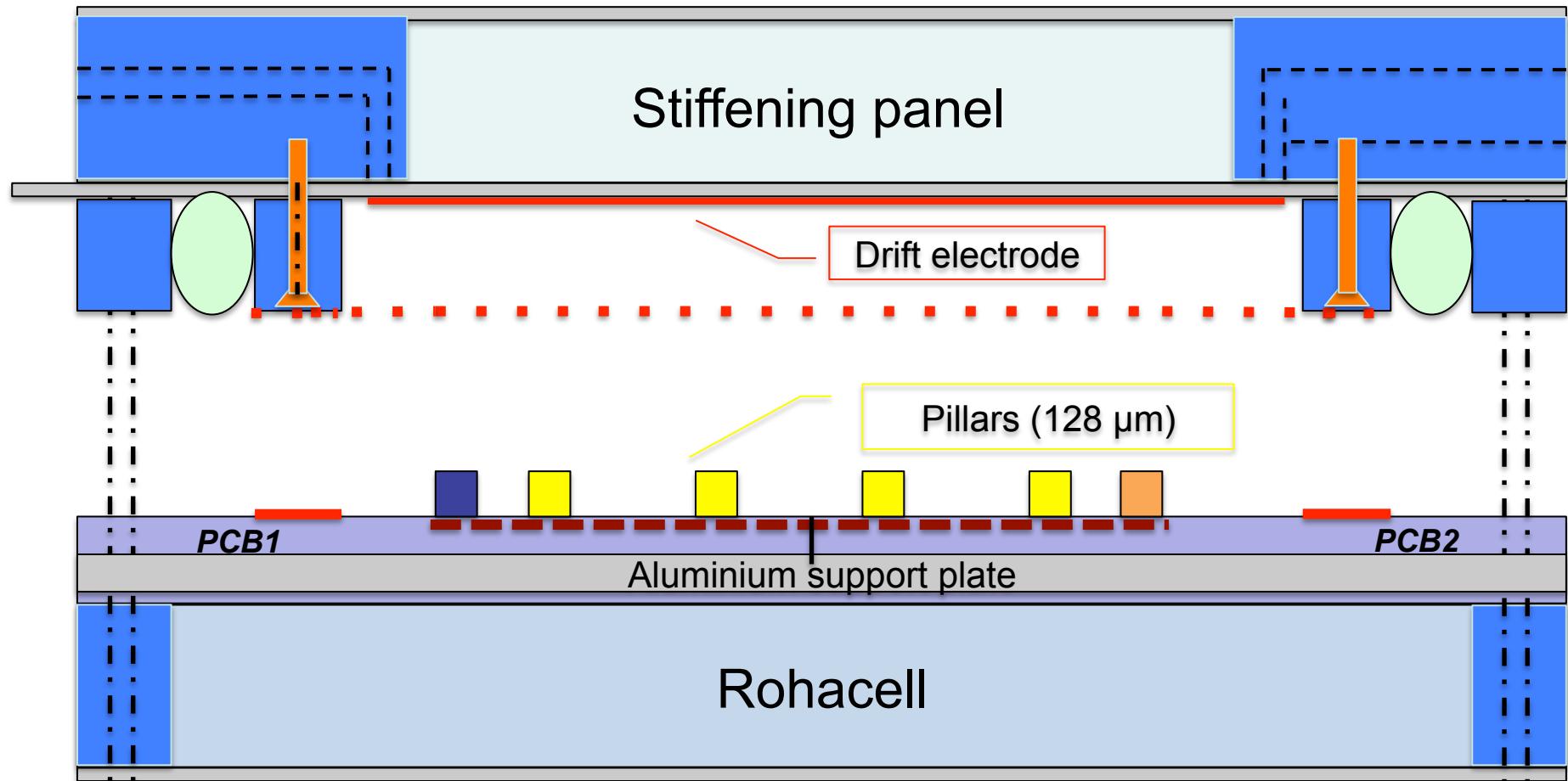
T1-8; $S=10 \times 10 \text{ cm}^2$; $p=0.4 \text{ mm}$; $dg=5 \text{ mm}$; $gG=10^4$; Ar-CO₂ 93-7; $v_d=47 \mu\text{m/ns}$; Elx=APV25; daq=SRS



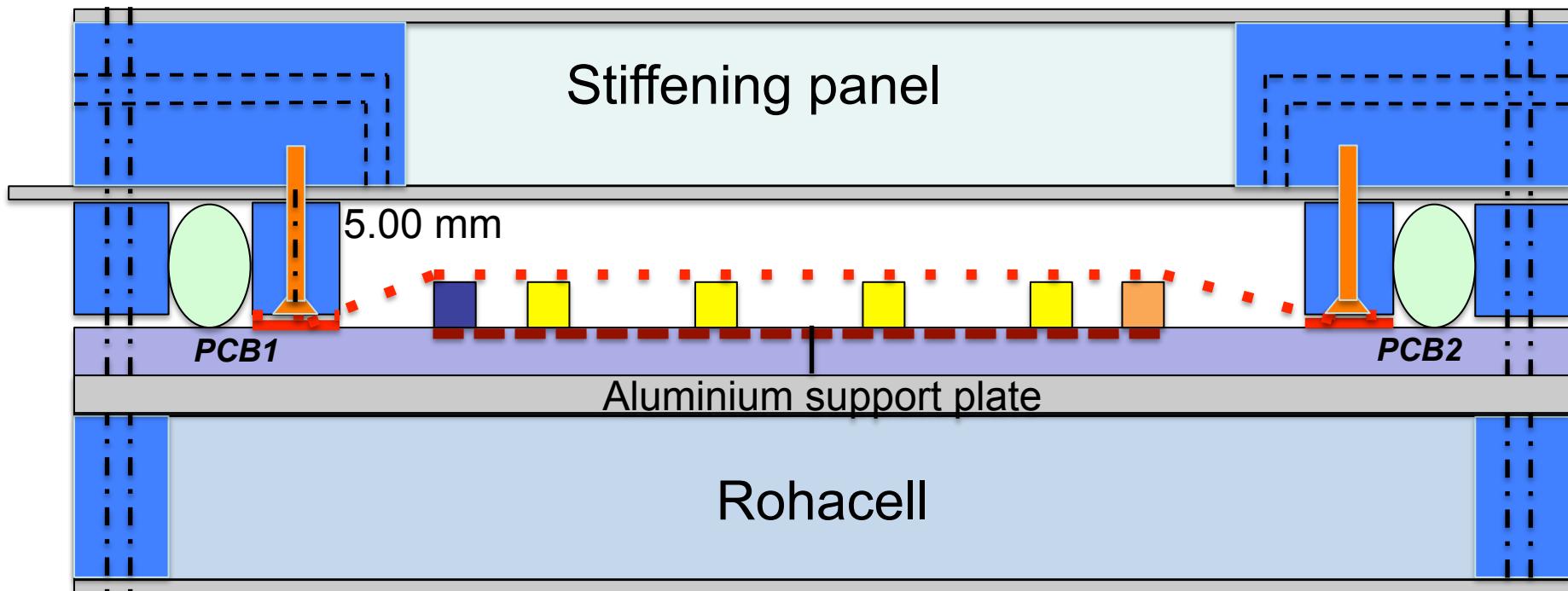
Track Slope Resolution as a function of angle



1 x 1 m² sketch (not to scale)



1 x 1 m² sketch (closed)



1 x 1 m² micromegas



1x1 m² readout board composed of 2 boards of 0.5 x 1 m²
2048 strips of 1.06 m length with a pitch of 0.45 mm

Drift electrode and mesh panel (top) and detail showing
the O-ring as gas seal

$1 \times 1 \text{ m}^2$ micromegas

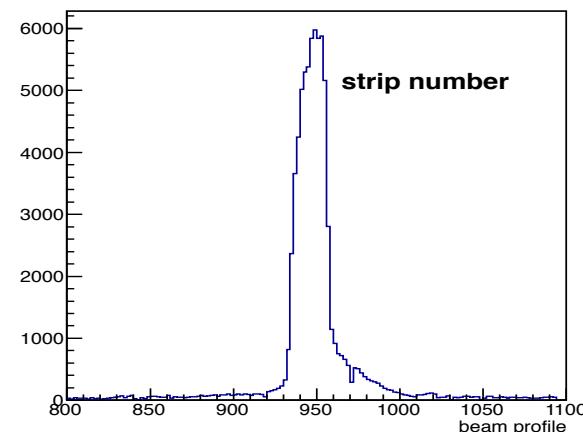
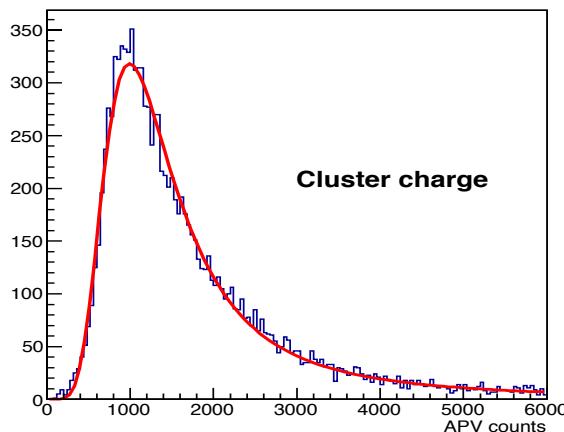
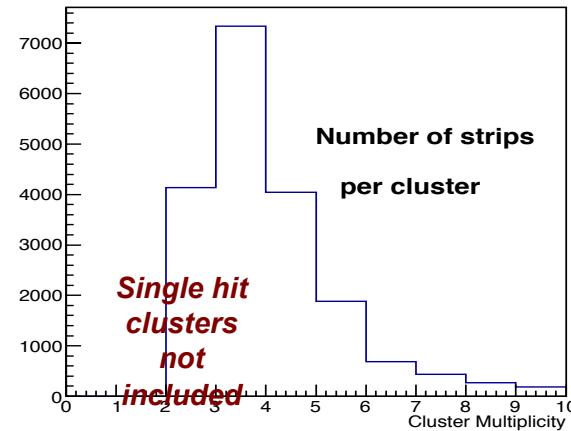
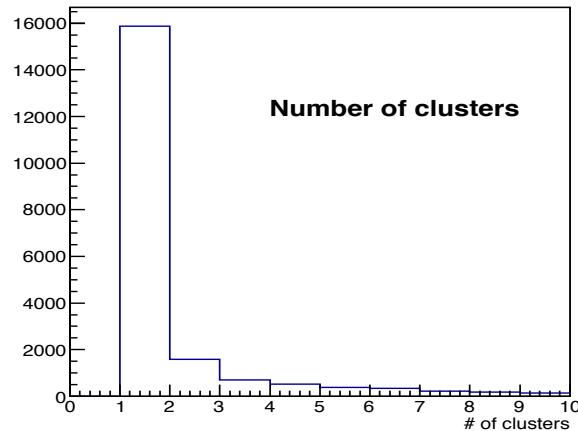


$1 \times 1 \text{ m}^2$ MM being closed in Rui's 'clean room'



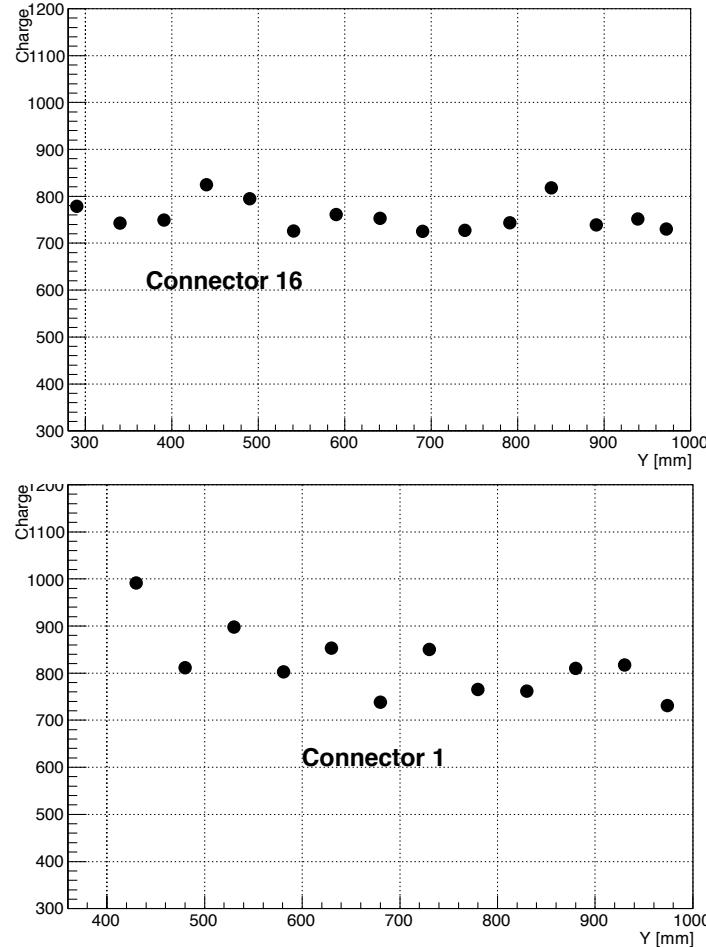
$1 \times 1 \text{ m}^2$ MM in H6 test beam

Performance of 1 x 1m² MM Test beam results (120 GeV pions)

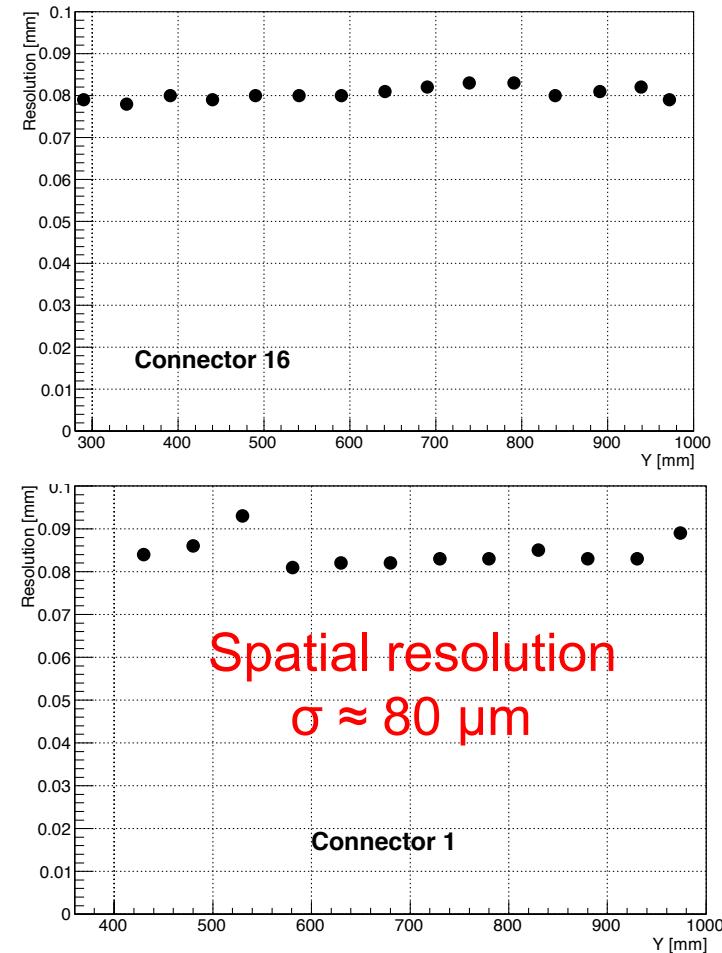


Typical distributions for H6 run

Performance of 1 x 1m² MM Test beam results (120 GeV pions)



Charge response along strip



Resolution along strips

Summary

- Micromegas Detector R&D in close collaboration with CERN
(Joerg Wotschack, Rui de Oliveira)
- Large area, discharge immune detector development
- BNL PC Lab involvement, liaison with U.S. Industry
- BNL focus in front end electronics, detector simulation,
electrode optimization, performance, data analysis
- Trigger concept development and implementation
- Generic R&D leading to ATLAS Muon System upgrade and
possibly to other future detectors